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CEAZA mega board: an open-source data logger for scientists

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ABSTRACT

Over the last decade many researchers have taken advantage of the technology boom related to the launch of the Arduino platform to make their own datalogging devices. Many of these developments ended with the first functional prototypes in which multiple electronic boards are mixed by wiring/soldering and then used in datalogging activities. In this study we present a new, simple, robust, and expandable datalogger board based on maker's community integrations. Our datalogger board extends previous work in this area as we designed an Arduino Mega 2560 derivative integrated board that is compatible with existing developments but was also designed and implemented considering requirements such as low power consumption, expandability, and integration. Different tests were made so reliability in low temperatures and low energy needs are satisfied. Is expected that the scientific community can add this board to their tool set, as this board solves the energy problem and present an easy transition from handmade logger integrations.

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1. INTRODUCTION

Since the Arduino project [1], [2] arrived onto the maker scene, many low-cost electronics applications [3] for data logging have proliferated as an alternative compared to the actual existing commercial equipment for scientist tools monitoring devices with high prices and volume like Arduino based loggers developed in [4]–[6]. Normally these developments have been focused on low-cost Arduino module integration through small and short wires, modifying the modules in some cases to get cheap electronics components-based data loggers. Such projects do not normally consider some variables when comparing the device costs such as a person-hours, required for device assembly. Said requirements are a barrier when an individual without an in-depth knowledge of electronics attempts to make a "low-cost device from scratch".

The worldwide growth of the maker scene [7]–[9] has been pushing a new business model for some PCB manufacturing companies, with the target being the fast manufacture of high-quality electronic hardware at competitive prices for low scale batches and approaching to a better quality products to a Do it yourself (DIY) projects [10]. In addition, the Arduino boards, the various cheap modules, and its Idle programming software have enabled the firmware development to be customized in areas outside of electronics, such as low-cost custom science [11], citizen sensing [12] and citizen science [13] applications.

In some scientific scenarios the field deployment for monitoring is difficult due to heavy commercial devices, with big and heavy battery banks and a vast required tool set for field operations. In extreme environments additional mounting solutions are often required. especially when drought less predictable under declining snowpack [14] could force to collect more environmental data for better future hydrologic understood. Accordingly, when monitoring is in remote areas, the operation become a logistical

challenge. When data input from multiple spots from a larger study sites are needed [15], the cost of instruments and data logger systems rises fast out of scientific budgets if using commercial devices. Furthermore, when the amount and density of required data allows a small tradeoff between quantity and precision of data, there is a way to develop a low cost equipment [16] based on Arduino boards.

Said boards are easy to use and to implement for new projects, however, they are not generally designed for low power consumption projects located in extreme condition environments. In addition, integrations are normally done by adding a real time clock (RTC), a secure digital (SD) memory card and energy modules to an Arduino board joining them by wiring and soldering, and so making each "logger system" is a labor-intensive process, which also make it increasingly unreliable as each system is potentially prone to different assembly errors.

Conversely, some projects of datalogging developments have the main focus in low power solutions beside the specific device application as in [17] and [18] for aquatic specific applications. Some developments have taken the Arduino based datalogging concept to the next level with an embedded data logging systems which still been compatibles with the Arduino idle for programming like the open-source Arduino logger (ALog) loggers project [19], which is easy to program and assembly a reliable low-power consumption logging system to persons without deep electronics knowledge. Moreover, other compact generic datalogging developments based on a programmable system on a chip (PSoC) systems can reduce hardware costs compared with an field programmable gate arrays (FPGA) based system but are not too easy for a user without deep knowledge of electronics and programming as compared in [20].

Taking this lack of standardized Arduino derivative integrated data logging equipment for scientific purpose, we have designed an open-source hardware (OSHW) [21] board with four main integrated components. The electronic design for the CEAZA mega is a derivative product based on Arduino Mega 2560 board [22] with low power consumption and an integrated solution for data logging and local wired communication principles, where it is not necessary to modify and solder cables to connect the microcontroller (MCU) with data storage module, RTC module and communications modules.

With the use of CEAZA mega board, any scale manufacturer [23] will be able to produce the logger for himself or for any other user [24] whereas that the user will be able to minimize the time for developing portable low-power consumption data logging solution for its custom monitoring and put the focus on the communications system and sensor integration.

2. RESEARCH METHOD

In this study we applied the waterfall model workflow [25], which is usual for software development processes, so the main parts of the process were easy to distinguish definition of requirements, product design, implementation and testing to validate the developed product.

2.1. Definition of requirements

The development of this board is part of a user-centered innovation process in which several years of prototyping and testing with different modules and boards were made in a context of a CEAZA environmental monitoring team working to extend the CEAZAmet automatic weather station (AWS) network with low-cost equipment to meet the hydrologic measurements increase requested by water manager communities [26], [27] in Coquimbo region.

Because this development was born from necessities of data collection inside the CEAZA monitoring teams, the whole electronic hardware design started with a list of specifications that should be satisfied according Table 1.

Table 1. CEAZA Mega electronic design requirements

Item	Expected result
Built in modules	MCU, microSD reader, RTC, voltage regulator, USB port, RS-232.
Operation temperature range	-30 to 60 °C
Power consumption profile	Optimized for long stand by periods between samples
Input voltage	7 to 12 V
Programming	Arduino IDE software by USB and generic ICSP terminal
Expandability	Must allow the access to MCU pins for general purposes and expansion boards
Special ports	Energy port, 1-wire sensor, PWM sensor, two status LED

2.2. Design

The main proposal is the design of a whole new development board derivative from Arduino Mega 2560 R3, which builds in all components necessary for basic datalogging applications (see Figure 1). To simplify the customized extension boards, a PCB shape and expansion pins terminal self-standard was defined.

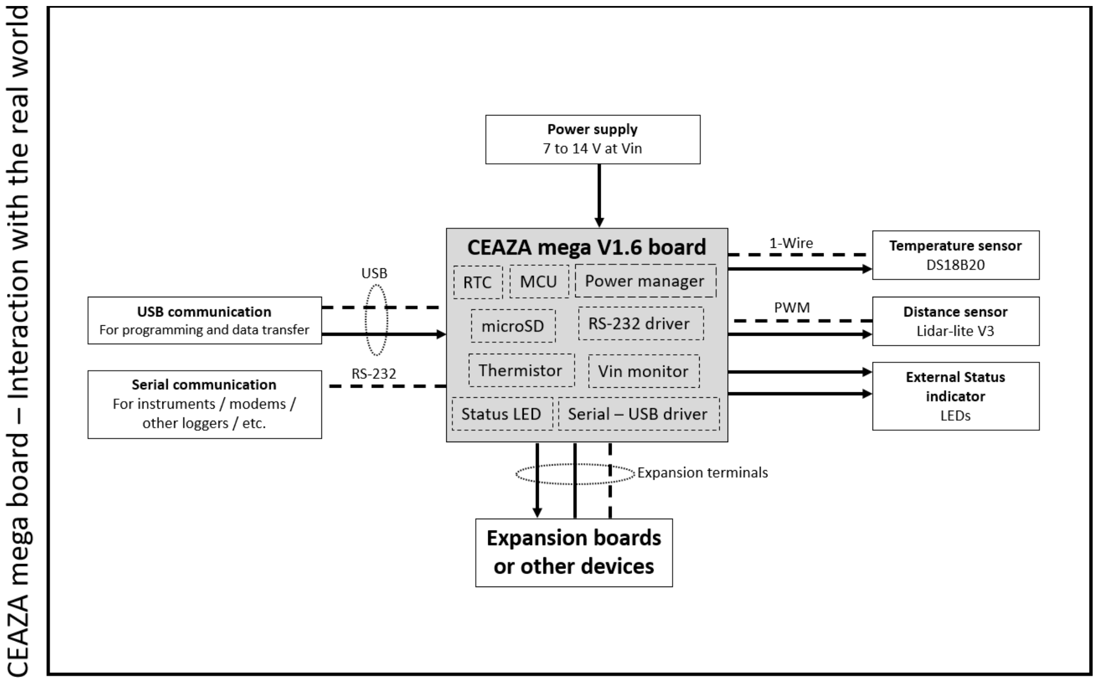


Figure 1. Flowchart of CEAZA mega V1.6 board interactions with external devices capabilities (Dashed lines indicate communication lines, simple line indicate digital, and analog I/O pins and arrowhead lines indicate power connection, where the tip of the arrow shows the electric current direction)

2.2.1. Dynamic power management

Low-power consumption is a fundamental design requirement to extend the device's autonomy [28]. One of the first and most important design decisions was to make every component of the system switchable for energy saving at extended sleep periods [29], so everything could be energized and de-energized by firmware and in runtime. Incorporating a dynamic power management scheme [30] at programming stage, enabled the minimum base consumption of the entire system to be reduced. Because this decision would imply that many digital output pins would be needed, this would impose a new requirement on the MCU related to the amount of IO pins, as every energy consumer component should have a digital controlled switch between the main power line and the energy input pin of the component.

2.2.2. Internal electronic system design

Based on previous prototype designs, functional requirements and expected operational algorithm, the electronic design was refined, selecting the components, and integrating them into the electronic hardware flowchart in Figure 2.

2.2.3. Microcontroller

As the system should allow a wider range of capabilities, the ATMEGA2560 MCU was selected. The ATMEGA2560 has a low power consumption when no I/O modules are activated. The minimum power consumption when the MCU is in active mode at 16 MHz and 5 V is near 20 mA. According to extra power consumed by extra built-in I/O modules such four UART, the SPI, I2C and ADC the power consumption can be increased.

The MCU is powered with a 5 V dc voltage regulator, thus its corresponding base current consumption when it is going to sleep is near 9.5 µA. Considering the datalogger standard intended use (short periods of activity taking measures, saving data and sleep for long periods of time), the active plus sleeping time is the way to calculate the system consumption.

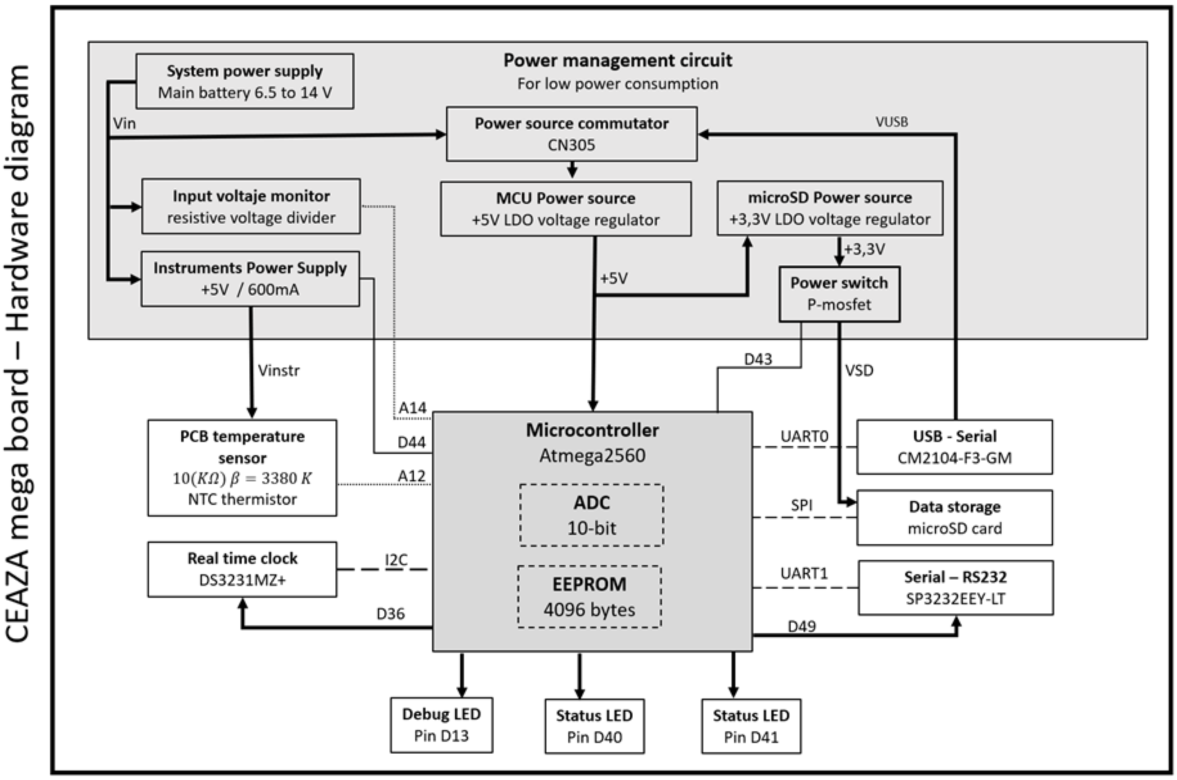


Figure 2. Flowchart of internal CEAZA mega hardware scheme (Dashed lines indicate communication ports connected, dotted line indicate internal board analog reads by MCU, simple line indicate power control pin connection and arrowhead lines indicate power connection, where the tip of the arrow shows the electric current direction)

2.2.4. RTC

To get the timestamp in every log, a DS3231MZ+ RTC is used as a Clock Calendar, with Leap-Year Compensation Up to Year 2100 and accuracy of ±5ppm, which means ±0.432 Second/Day drift. Besides, the RTC included a backup battery connection pin to keep date and time running even without powering the device up to 13 years considering a coin cell CR2032 with 235 mAh of capacity as backup battery. This is communicated by I2C with the MCU.

The RTC module requires a Standby Supply Current of 200 µA which is nearly 21 times the MCU power consumption in Power-save mode. In order to reduce the total power consumption during data logger sleep time, the RTC is powered only when the timestamp is requested by the MCU (controlled by firmware).

2.2.5. Data storage

To store the logs for long periods of data recording (two years at least), a microSD socket communicates with the MCU by SPI through a voltage translator due the MCU uses 5 V logic and the microSD card uses a 3.3 V logic. The data storage is written in an ASCII text document for easy understanding and processing by human user [31], where every log is a line of all data read and every field is separated by a comma. A removable data storage simplifies data collection process by just changing the microSD card from device and then retrieve the logs in a more comfortable place and time by computer operations. In addition, the data captured must be able to be saved in a physical and logical format so that they can be easily integrated into systems with FAIR policies as defined in [32]. For low-power consumption during sleep mode, a P-channel MOSFET deliver controlled power to the microSD card only when a read / write process is requested by the MCU (controlled by firmware).

2.2.6. USB - virtual COM driver

For serial programming the device through UART0 as an Arduino mega board, an USB to UART bridge chip is integrated and powered only by the USB cable from the host computer to avoid waste of energy when the bridge is not in use.

2.2.7. Communications

CEAZA mega is able to communicate with other external devices, such a modem, instruments, other dataloggers, etc. For said purpose, the board has multiple ways, such as four UART, one i2c bus and one SPI bus. Some ports have been used internally by the same sub-systems component, as the UART0 dedicated for USB driver and theUART1, dedicated for RS-232 driver. The RS-232 driver is powered on only when the communication over RS-232 is able for low power consumption operations (controlled by firmware).

2.2.8. Power supply

To reduce the device's power consumption, only the microcontroller is always powered on with a dedicated low quiescent current (2 μA) LDO regulator, which is capable of supply 5 V, 250 mA with a wide input voltage from 5.7 V to 13.2 V, meanwhile the MCU itself can activate or deactivate the power source of any other subsystem according to the uploaded firmware. The power input plug includes a rectifier diode dedicated to protecting the board against involuntary reverse polarization.

To facilitate program by just connecting the device to the computer, a power commutator has been added to the USB Mini-B receptacle terminal, which supplies power from the USB host to the MCU, microSD card, RTC and RS-232 driver, when it is not powered by a self-power supply e.g., 12 V battery. Conversely, when the data logger is already powered when the USB is connected to the host, the bus only supplies power to the USB to UART bridge. The power commutator system has an "energy cost" associated, which is mainly given by the voltage detector circuitry self-power consumption which its near 21 μA.

To supply power to the external sensors the CEAZA MEGA includes a controlled high frequency (2MHz) step down switching regulator, configured to deliver 5 V and up to 600 mA and only uses a 3 μA when its disabled. The regulator is activated when the pin D44 (port PL5) of the MCU is high and disabled when D44 is LOW.

The 3.3 V power supply for SD card is supplied by a low quiescent current (1.6 μA) LDO voltage regulator connected in cascade to the 5V of MCU LDO regulator, which can deliver up to 250mA. The RS-232 driver is powered by a D49 (port PL0) MCU pin also, so it must be used carefully to avoid damage to the D49 pin. According to driver's manufacturer power consumption at speed communications, the communication by RS-232 should be up to 9600 bps to keep the current consumption of pin D49 under the safety zone (< 20 mA per pin).

2.2.9. Additional motherboard addons

A reset button is included on board for easy firmware tests when programming the device and according to Arduino boards. For Arduino Mega 2560 board basic blink LED program compatibility, an LED is connected to D13 pin, which is useful for firmware debugging during program writing. To monitor the battery status and know the discharge rate, a system power supply voltage is integrated in data logger circuitry and its able to be accessed as a field in the logs or dynamic power management scheme control input.

CEAZA-MEGA has electronics selected to operate under a defined temperature range. Most components can operate in a wider temperature range. Though connectors mostly limit the temperature operation near declared device operation temperature range. For optimal device operation monitoring, a negative temperature coefficient (NTC) thermistor $10\ (K\Omega) \pm 1\%\ \beta = 3380\ K$ was implemented. The PCB temperature monitor is powered when the integrated step-down power supply is activated. Accordingly, the PCB temperature reading are not available when the board is powered only by the USB port. The PCB temperature data is available to the user. I2C pull-up resistors: The I2C circuits has a couple of 10 kΩ pull-up resistors are connected to MCU's I2C pins for direct I2C devices connection.

2.2.10. Off board temperature sensor

As almost all low-cost weather-related monitoring include temperature readings, a connector for a DS18B20 sensor was included in the board, this sensor is a low cost, 9 to12 bit digital thermometer. The DS18B20 communicates over 1-wire bus, has wide operation temperature range -55 °C to +125 °C with ±0.5 °C Accuracy from -10 °C to +85 °C and low power consumption 1.5 mA at active current and 1 μA in standby mode. The DS18B20 is widely used in the maker scene, thus is easy to integrate to an Arduino system, and has been demonstrably reliable for low-cost weather monitoring applications in [33], [34]. So, it can be used to record a base system temperature.

2.2.11. I/O modules

For other analog signal readings, the electronic board has 12 pins dedicated for 10-bit, 0 to 5 V input ADC corresponding with A0 to A11 Arduino pins. Furthermore, the board has 26 digital I/O pins available for general digital purposes including 11 pins supporting 8-bit 490 Hz PWM output (D2 to D12 Arduino pins) and 2 external interruption pins (D2 and D3 Arduino pins). For MCU flash programming an ICSP 2x3

pin header is on board which allow to program with multiple tools plus Arduino programming environment such AVRISP mkII, STK500 among other 8-bit AVR microcontrollers ICSP interfaced compatible programmers.

2.2.12. PCB shape standard

A sole board shape and pinout standard has been defined to allow customized modular-based expansion boards compatibility and simplify new prototypes [35]. The CEAZA mega shape is a semicircular board 69 mm diameter to fit into a low-cost 70mm diameter PVC sanitary pipe as a low-cost enclosure or well in a small watertight box. The board includes three 2x10 pin headers with all power and signal pins available for general purposes (see Figure 3).

The U1 terminal has dedicated pins for analog inputs and power sharing though the boards. The U2 and U3 terminal are for communication and digital I/O pin access. The main concept for expansion boards is to fit as a sandwich board added down the main board. The expansion boards should have a pin header for the top side and receptacle pins for the bottom to attach other expansion boards to the systems if it's necessary for the project.

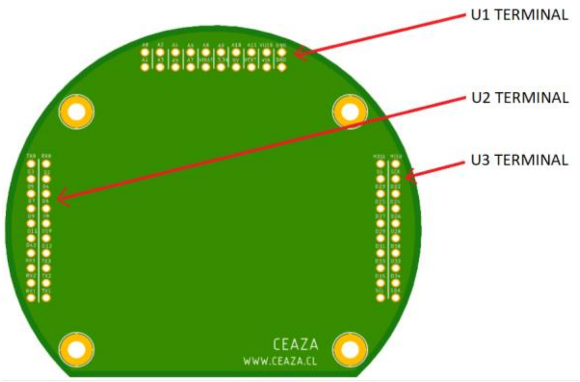


Figure 3. CEAZA mega PCB shape and terminal pinout standard layout to start expansion boards for the system

2.2.13. Board pinout

Any other device or expansion board integrated to the board should be connected to the U1, U2 and U3 terminals considering its defined pinout (see Figure 4).

2.3. Implementation

After the board was complete in design stage a batch of 10 units were fabricated and ready for bootloader upload. In Figure is possible to see the finished product, which can be stored inside on a cheap 70 mm diameter PVC sanitary pipe.

2.3.1. IDE and firmware uploading

Arduino Ide is a widely used firmware platform in the maker scene due is a complete free microcontroller programming solution for embedded systems firmware, easy to use and to find support on the internet. In this way, it is convenient that the CEAZA mega has the Arduino bootloader on its flash to become an Arduino derivative board. The bootloader is uploaded on the CEAZA mega board from the same Arduino IDE by the ICSP terminal through another Arduino board with the example sketch “ArduinoISP.ino” or any other AVR 8-bit MCU programmer. Once the bootloader is uploaded in the CEAZA mega’s microcontroller, the sketches can be uploaded to the board by its USB mini terminal as an Arduino Mega 2560 board. Other programming methods, software and tools by 6-pins ICSP interface are allowed according to user programming preferences.

2.4. Testing

The first produced batch was tested under expected operating conditions such as the low power consumption, the operating temperature range, data integrity and energy autonomy. To do this, a board library and a test firmware were implemented, and then tests were performed for a range of temperature and energy levels scenarios.

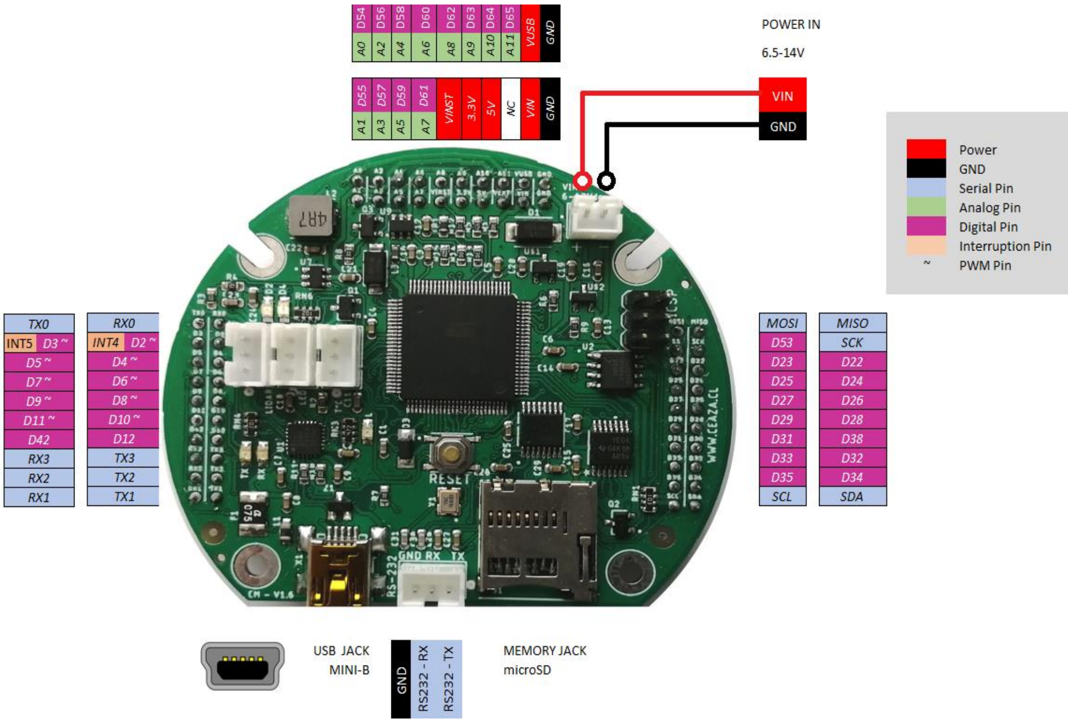


Figure 4. CEAZA mega V1.6 data logger pinout standard

2.4.1. Firmware tests

Given the general algorithm of a logger and the specific characteristic of this board, such as power on-off pins and other considerations a core library "CEAZAMEGA.h" was implemented and then a test sketch was programmed (see Figure 5). The test firmware does the following actions: initialize, measure, save data, sleep until next measurement.

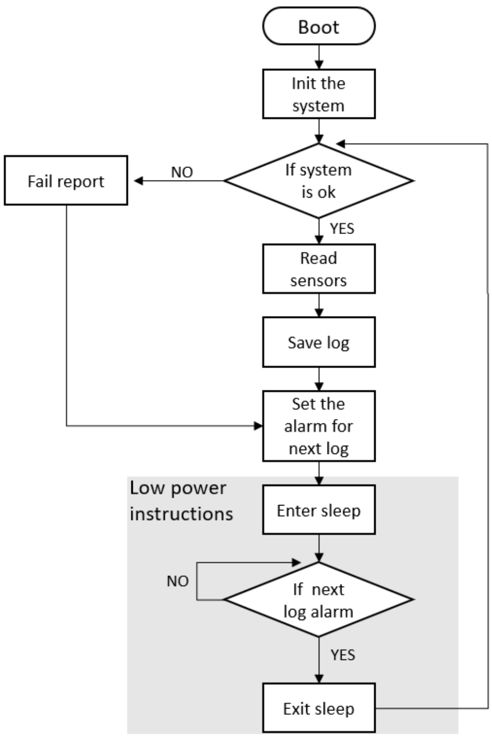


Figure 5. CEAZA mega test sketch flow chart

2.4.2. Power consumption

It is possible to calculate an approximation of the average current consumption of a device according to the ratio of time that it is awake, which can be described as (1).

$$i_{mean} = i_{sleep} \cdot t_{sleep} + i_{on} \cdot \left(1 - t_{sleep}\right) \tag{1}$$

where i_{mean} is the mean current consumption of device, i_{sleep} is the current consumption when the device is on sleep mode, t_{sleep} is the sleep time rate (between 0 and 1) and i_{on} is the current consumption when the whole system is operative.

The current consumption at sleep mode is given by (2).

$$i_{sleep} = i_{\mu C-sleep} + i_{q5v} + i_{q3v3} + i_{p.s.off} + i_{monitor} + i_{commutator} + i_{translator-off} \tag{2}$$

where $i_{\mu C-sleep}$ is the MCU current consumption at sleep mode, i_{q5v} is the 5 V regulator quiescent current consumption, i_{q3v3} is the 3.3 V regulator quiescent current consumption, $i_{p.s.off}$ is the instruments power supply quiescent current when is disabled, $i_{monitor}$ is the current drained by the Vin monitor, $i_{commutator}$ is the power supply commutator current consumption and $i_{translator-off}$ is the microSD voltage translator current consumption when it's disabled.

The current consumption during awake mode is based on the worst scenario, where every internal subsystem is actively working.

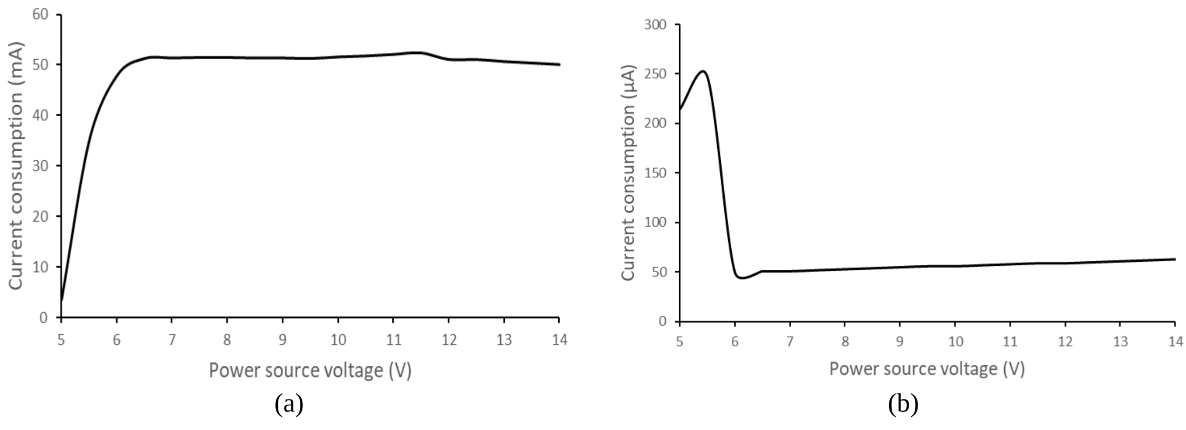
$$i_{on} = i_{\mu C-awake} + i_{q5v} + i_{q3v3} + i_{p.s.on} + i_{monitor} + i_{commutator} + i_{RTC} + i_{microSD} + i_{RS232} + i_{temp} \tag{3}$$

where $i_{\mu C-awake}$ is the MCU current consumption at idle mode, $i_{p.s.on}$ is the instruments power supply current consumption when its enable, i_{RTC} is the RTC current consumption during date and time reading, $i_{microSD}$ is the microSD current consumption in a write process, i_{RS232} is the RS-232 driver quiescent current and i_{temp} is the current drained by the PCB temperature sensor calculated by the Vin side (due the dc – dc switched instruments power supply).

$$t_{sleep} = 1 - \frac{t_{on}}{3600(s)} \tag{4}$$

where t_{on} is the time in seconds that the device is awaked in an hour.

As the same analysis shown in development calculations, the power consumption is performed in all its consumption states, such as sleep, idle, during measuring sensors and the worst-case scenario (see Figure 6). The current measurements are performed at 17 °C and 58% relative humidity and the data is stored in a SanDisk Ultra 16 GB class 10 microSDHC card. The CEAZA MEGA board tested is V1.6 from batch 290105A_Y53-210508.



(a) (b)

Figure 6. CEAZA mega current consumption at different input voltages (a) at active mode and (b) at sleep mode

The current consumption during Idle mode shown in Figure 6(a) was measured with all peripherals powered off and the MCU at active mode. When the LDO 5 V voltage regulator reaches its stable state near 6.5 V system input voltage, the board current consumption does not have significant variation up to board maximum input voltage tested (14 V).

At sleep mode shown in Figure 6(b), there exists a current consumption variation when the voltage increases. meanwhile at lower voltages than 6.5 V (out of operating voltage range) the current rise near to 250 μA. Because all the integrated elements except the MCU have power control, the Table 2 show the current consumption at different operation modes.

Table 2. Current consumption at 12 V input of CEAZA mega board at different working modes

MCU Operation	Current consumption (mA)
Sleep mode	0.059
idle mode	49.6
idle and SD on	49.9
idle and RS-232 on	51.4
idle and RTC on	49.7
idle and Vinstr on	50.3
sleep and all components on	2.4
idle and all components on	52

2.4.3. Operating temperature test

All components used by design can work from -40 °C to 85 °C. The minimum temperatures recorded by CEAZA at the Andes Mountain in the Coquimbo region are usually no lower than -25 °C. The operating temperature tests are performed in three stages, conditions which include low temperature tests, near -20 °C, room temperature test, any temperature between 15 °C and 25 °C and high temperature tests, near 50 °C.

For the temperature test perform, the board is powered with a 12 V SLA 1.2AH battery and stored with the battery and silica gel bags inside of a watertight box (see Figure 7). The board every minute read the PCB temperature with its built-in NTC thermistor, get the battery voltage, save the data in the SD card with the respective time stamp and then go to sleep. The retrieved logs from microSD card after tests was at perfect conditions, without lack or corrupted data.

The PCB temperature registers shown in Figure 8 describes the three-test performed. The first test was performed at freezer at -24 °C (dash double-dot in Figure 8), the second test was at room temperature (continuous line in Figure 8) and the last test was performed at heated chamber configured to 45 °C (dashed line in Figure 8).

Figure 7. CEAZA mega logger tested at different temperatures inside a watertight box and with desiccant to avoid condensation on the electronic elements

Based on measured current consumption and according to (1), if the device is powered by a 12 V 5Ah SLA battery and awake 1 second every 10 minutes for read sensors and save data, the average current consumption i_{mean} is 147 μA, which means near 3.8 years of autonomy. Accordingly, the low energy consumption is achieved for remote monitoring applications with extended time between logs.

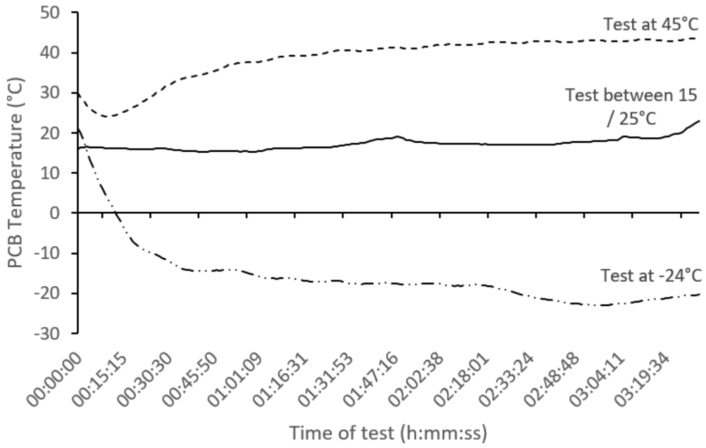


Figure 8. Logs registered with CEAZA mega PCB temperature sensor at different operation temperatures

2.5. Product specification

Developed product share the core with the Arduino Mega 2560 board, nevertheless, some differences in design bring differences in its specifications. At Table 2 is possible to find specific CEAZA mega specification and capacities.

Table 2. CEAZA mega specs

Parameter	CEAZA mega V1.6
MCU	Atmega2560
Clock (MHz)	16
Program memory (KB)	256
Variable memory (KB)	8
EEPROM (KB)	4
Logic tension level (V)	5
Arduino bootloader	Arduino Mega 2560
MCU power profile	Always on
RTC drift (s/day)	±0.432
RTC power profile	Controlled by firmware, built-in backup CR2032 coin-cell battery
Data storage	removable microSD card
microSD capacity (GB)	≤ 32
microSD power profile	Controlled by firmware
MCU dedicated RS-232 port	UART1
RS-232 pins	Tx, Rx and GND
RS-232 baud rate (bps)	≤ 115200
RS-232 power profile	Controlled by firmware
UART channels	4
SPI channels	1
I^2C bus	1
Analog input	10-bit (12)
Digital I/O	26
External Interrupt	2
PWM output	12
Programming port	ICSP, UART0 (through USB)
Built in LED	3
Built in sensors	PCB temperature, Vin monitor
External sensors terminals	1-Wire bus, PWM reading
External LED terminal	2
Instruments power supply	5 V
Instruments current capacity	600 mA
Instruments power profile	Controlled by firmware
Input voltage (V)	6.5 / 13.5
Power (sleep) (µA)	60
Power (awake) (mA)	50
Width (mm)	60
Length (mm)	69
Operation temperature (°C)	-24 / 45
Mass (g)	28

3. RESULTS AND DISCUSSION

This project has been designed and produced a complete low cost, low power consumption open–source Arduino derivative built-in microSD + RTC data logging and serial RS-232 system with direct compatibility with some low-cost sensors as the 1-wire DS18B20 digital temperature sensor chip. It has been successfully tested in low temperature operations and very low energy consumption at sleep mode without sacrificing MCU memory and computing power has been achieved compared to the previous developments presented on this paper as shown in Table 3.

The board can be easily integrated with already made developments as the core components are commonly used by the maker's community and is already compatible with Arduino Ide. For more accurate and customized designs, this is an open-source-hardware project where anyone can modify its design or develop any expansion board according to new users' needs and assembly resources [36]. The product is equipped with access to MCU pins in order to be used for any low-cost data logging application or compatible with some expansion board designed for it.

Table 3. open-source dataloggers benchmarking

	Cave Pearl	ALog BottleLogger 3.0	Ceaza mega 1.6
Input voltage (V)	3.6 – 6	2.5 – 12	6.5 – 13.5
Power (sleep) µA	100	80	60
Power (awake) mA		11.9	50
MCU	ATMega328p	ATMega644p	ATMega2560
Clock (MHz)	8	8	16
Program memory (KB)	32	64	256
Variable memory (KB)	2	4	8
EEPROM (KB)	1	2	4
External interrupts	2	2	4
Analog input	10-bit (7)	16-bit (16)	10-bit (12)
Digital I/O	14	6	26
I2C	1	2	1
SPI	1	1	1
UART	1	1	4
Data storage (GB)	4	32	32
RTC drift (s/day)	±0.432	±0.432	±0.432

The product is lightweight and portable for reliable applications in remote areas. The board is ready to program in order to avoid wasting time integrating the basic modules such an SD module, RTC module, RS-232 module and power management module, for data logging applications, which could result in unnecessary points of failure.

After finishing and testing the CEAZA MEGA board performance in its different situations, it is possible to consider professional low-cost hardware developments from open-source community as an alternative when specific operating requirements need to be meet. The approximate development cost of this board is estimated to be in the range of 20k-30kUSD in a timespan of two years by a team of two professionals; an electronic engineer for hardware and a computer engineer for firmware, also scientists that make field data use were incorporated mostly in the requirement collection parts as they would be the end users. All of this are estimated calculations as this product was only part of a larger project and the first tests were performed previously.

4. CONCLUSION

Hardware devices from and for the scientific field research has seen great interest and advances in the recent years, and this has enabled makers and scientist around the globe to design and implement specific hardware and software packs that satisfies their specific needs. We have presented a new datalogger electronic board designed and implemented from a scientific wise operational perspective, this new datalogger electronic board helps in filling a gap between hobbies and researcher's handmade devices and commercial systems, so it is expected that devices like this would take one step forward, thereby advancing field experiments that depend on data logging with special needs, as low cost, and low energy consumption. This paper includes not only the results, but also the used methodology so new developments could follow the same process of design/implementation providing a simple but structured workflow.

Future work will be focused first on the development of modules that allows to expand the capabilities of the board completing the system, so that set boards will be implemented to add energy and wireless communications. Subsequently a full system implementation that is ready for field deployment will be completed.

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